Management Plan

SECTION TWO

Chapter 3:
Definitions, Strategy, and Habitat Ratios

Chapter 4:
Current Conditions

Chapter 5:
Future Projections

Chapter 6:
Monitoring & Evaluation

Chapter 3:

DEFINITIONS, MANAGEMENT STRATEGY, AND HABITAT RATIOS

This chapter contains the standards used to judge current conditions of lynx habitat and guidance used to direct future activities on DNR-managed lands within lynx range. The first section identifies the desired future condition for landscapes containing lynx habitat managed by DNR. The classification system used throughout the management plan is defined in the second section. In the third section, quantitative habitat ratios for each component of the classification system are developed, based on what can be derived from the literature. Lastly, lynx habitat management guidelines are listed, including supporting literature.

3.1 Desired Future Condition Statement

Synthesizing the concepts developed in the previous chapter, the following qualitative description of a lynx landscape represents the "desired future condition" for DNR-managed lands (Table 7). This vision is the expected outcome of the quantitative habitat ratios and guidelines described in the next sections.

Table 7: Desired future condition of lynx habitat on DNR-managed lands.

A balance of stands in different structural stages is achieved that minimizes the probability of long-term adverse effects to lynx, realistically reflects the land's potential as lynx habitat, integrates other forest resource concerns, and reflects the current understanding of lynx habitat requirements:

1) prey habitat (hunting habitat) is interspersed throughout the landscape and connected to other prey habitat via other forested stands,

2) denning areas are adjacent to, within, or near prey habitat, connected by other forested stands,

3) human-related disturbance is managed at acceptable levels,

4) forested connections to adjacent lynx habitat, including that in British Columbia, are maintained.

Also, harvest unit plans are sensitive to the probability of extirpating lynx associated with actions that result in non-lynx habitats by:

a) dispersing harvest units in relation to existing lynx habitat elements, and
b) ensuring adequate regeneration within harvest units.

3.2 Classification of Lynx Habitat

Classification of landscapes from the perspective of lynx simplifies monitoring of habitat changes through time. Objectives of a habitat classification system are therefore to not only define types of habitat that mimic how lynx use landscapes, but also to provide categories that can be assessed without prohibitive costs. Because numerous variables influence lynx habitat use, it is expected that not all observations of lynx habitat occupancy will precisely fit the classification system. However, the system provides a foundation that can be adjusted as more information concerning lynx habitat relationships are obtained.

The classification system used in this plan recognizes five basic lynx habitat categories, including 1) Open Areas, 2) Forage Habitat, 3) Denning Habitat, 4) Travel Habitat, and 5) Temporary Non-lynx Areas. Open Areas are separated from the rest of lynx habitat at the landscape level. Within lynx habitat, currently forested habitats (Forage, Travel, and Denning Habitat) are separated from areas which have potential to become lynx habitat in the future (Temporary Non-lynx Areas). Additional lynx habitat components, travel routes, travel corridors, and den sites are also recognized.

3.2.1 The Landscape: Open Areas

The first logical step in a habitat classification system is to separate those areas within a landscape that are potentially useable by lynx from those that are generally avoided (Table 8, Fig. 6). For instance, Breitenmoser and Haller (1993) calculated home ranges for European lynx by adjusting the observed home range to exclude the treeless alpine areas. When WDW (1993) calculated lynx densities for Washington State, they extrapolated lynx densities from the average lynx density within the Okanogan study area (Brittell et al. 1989, Koehler 1990a) to the acres of *suitable* habitat within the state, excluding generally avoided habitat types.

The matrix of a lynx landscape includes all lands capable of supporting "forested" conditions; that is, stands that meet at least the minimum habitat standards for lynx. According to Koehler and Brittell (1980), such stands must contain at least 180 trees per acre [tpa] and be at least six feet tall where snows reach 2-3 feet, so as to provide enough cover to hide and shelter lynx in winter. This estimate was derived from Koehler (1990a), who observed that lynx crossed stands thinned to 170-260 tpa (420-640 trees/ha). These trees were 5-9" dbh, and no understory cover was present.[18] Alternatively, WDFW (1996) hypothesized that stands with fewer but larger trees that provide at least 70% canopy closure may provide "forested" [travel] conditions when "vertical structure" exists 4-8 feet above ground.

In this plan, "Open Areas" refer to all sites that cannot maintain 1) at least 180 tpa where tree height reaches at least 3.3 feet (1m) above snow level, or 2) canopy closure of at least 70% (as described above). These areas are generally avoided by lynx and can be characterized as non- or sparsely forested areas, including talus slopes, exposed rock surfaces, meadows, shrub fields, and other "permanent" openings (Brittell et al. 1989, Koehler 1990a, Staples 1995; 2.1.4). These areas are colored dark brown on the maps within this document to indicate their lack of forested potential (Fig. 6).

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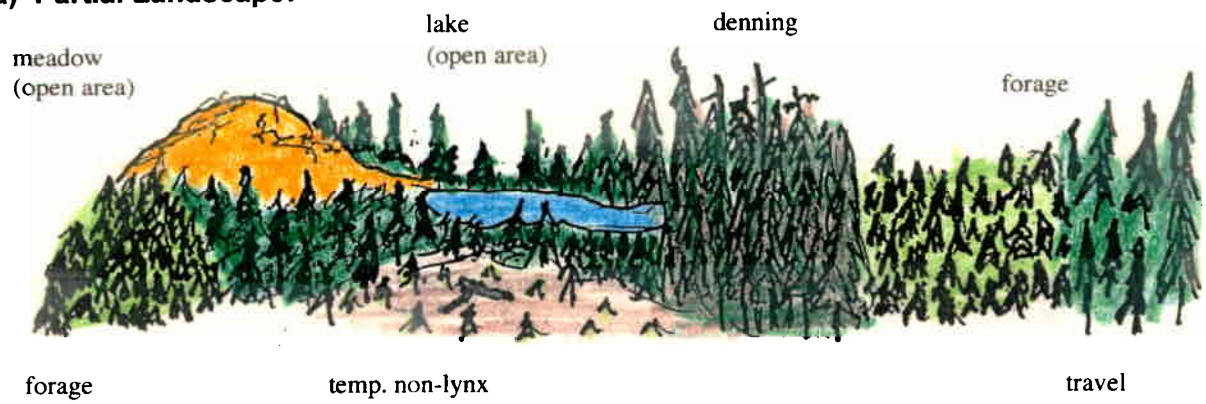
[18]B. Slough (Yukon Dep. Renewable Resour., pers. commun.) concurred by stating that "lynx will rarely cross an opening >1,968 feet (600 m), and most crossings are <328 feet (100 m). Narrow travel corridors (328 feet or 100 m), of fairly open pine with sparse understory are sufficient."

Table 8: Lynx habitat classification system of DNR's Lynx Habitat Management Plan (five major habitat categories in **bold**).

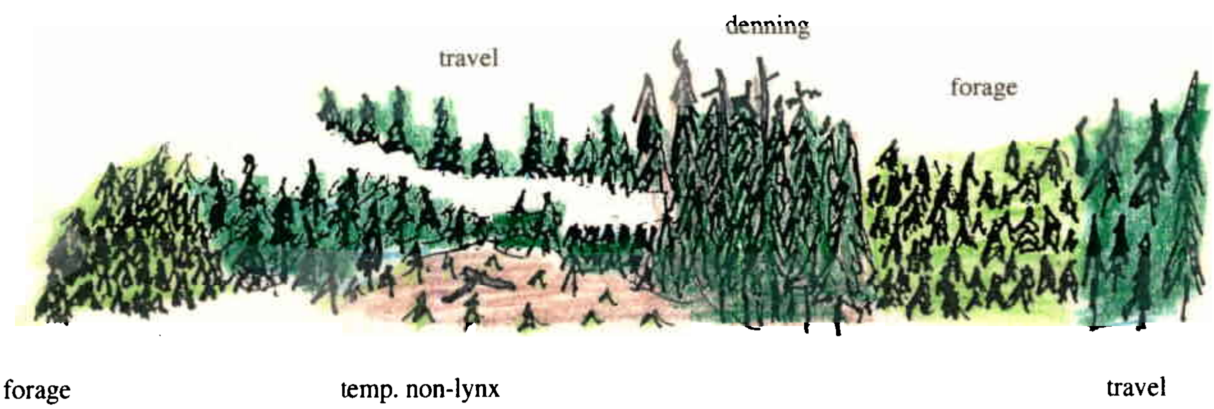
Component	Description
Landscape Level Matrix	
Lynx Habitat	All habitats potentially used by lynx, either currently or in the future: areas capable of maintaining ≥180 tpa (445 trees/ha) or ≥70% canopy closure of mature trees, with trees in both cases at least 3.3ft (1m) taller than avg. snow level.
Open Areas	Areas generally and permanently avoided by lynx: "permanent" or "natural" openings (e.g. meadows, lakes) not capable of meeting the requirements of lynx habitat.
Non-forested Components within the Lynx Habitat Matrix	
Temporary Non-Lynx Areas	Areas temporarily avoided by lynx, in the process of becoming Forage or Travel Habitat: recently harvested, burned or other early successional sites, not yet attaining Forage or Travel Habitat status.
Forested Components within the Lynx Habitat Matrix	
Forage Habitat	Habitat where lynx consistently find high densities of snowshoe hare, especially in winter: stands with at least 40% horizontal cover provided by small diameter stems and branches, available at least 3.3 ft (1m) taller than snow level.
Travel Habitat	Forested habitat not otherwise classified as Forage Habitat or Denning Habitat, with trees at least 3.3ft (1m) taller than avg. snow level.
Travel Routes	Linear landscape-level features that lynx often follow, such as major ridges, saddles, or riparian areas along rivers and streams.
Travel Corridors	A special management zone at least 330 ft (100m) wide along Travel Routes, maintaining Forage, Denning, or Travel Habitat within the zone.
Denning Habitat	Habitat where lynx prefer to den: mature to over mature subalpine fir or Engelmann spruce associations;* N or NE aspects; containing den sites.
Denning Sites	The specific structure that lynx use as dens: maximum number of jack-strawed down logs in area, given fire and regeneration concerns; layered 1-4ft (up to 1m) tall, using the largest diameter material available.

*Williams and Lillybridge (1983)

a) Partial Landscape:



b) Lynx Habitat Matrix within the Landscape: *less permanently open (avoided) areas*



c) Forested Lynx Habitat: *less temporarily open (avoided) habitats*

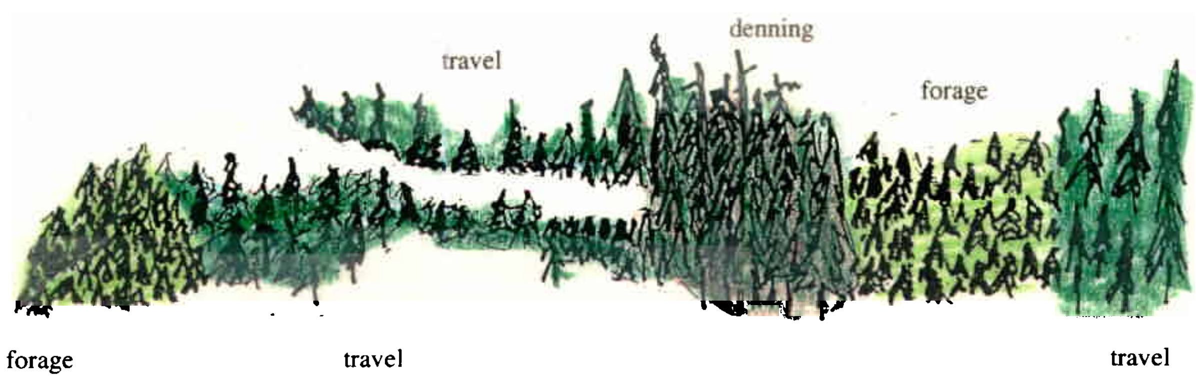


Figure 6: The lynx habitat classification system of the Washington Department of Natural Resources Lynx Management Plan.

3.2.2 The Landscape: Lynx Habitat Matrix

The lynx habitat matrix is made of three types of forested habitat (Forage, Denning, and Travel Habitat) and Temporary Non-lynx Areas.

3.2.2.1 Forested Habitat

The second level of lynx habitat classification separates those areas that have potential to be currently occupied by lynx from those that are temporarily avoided. "Forested Habitat" includes those stands that *currently* have at least 180 tpa or 70% canopy cover, and are at least 3.3 feet (1 m) above snow level. The green shaded stands on the maps reflect current Forested status (Fig. 6). Stands that do not currently meet this definition, but have the potential to meet it in the future are categorized as "Temporary Non-lynx Areas" until they grow into a Forested Habitat category. Within the portion of the lynx landscape that is currently Forested, lynx acknowledge at least two elements: 1) areas to hunt and sustain prey, and 2) areas to den.

3.2.2.1.1 Forage Habitat

Lynx in Washington are currently limited by areas to hunt and sustain prey, or "Forage Habitat" (Table 8, WDFW 1996). Although lynx probably consider all forested habitats as forage habitat and include whatever can be captured as prey, the category was simplified in this plan to include only those habitats that typically support high densities of snowshoe hare. In effect, the total area providing forage habitat will be larger than indicated because hares occupy other forested areas at generally lower densities (e.g. Koehler 1990b). Meanwhile, Forage Habitat includes stands with various histories and classifications according to traditional forest practices, that have the structure near ground and snow level capable of supporting hares. For example, Forage stands may originate from wildland fire, clearcuts, thinning of midsuccessional stands, or partial harvests of mature stands.

To encourage lynx persistence, prey must not only be abundant, but also vulnerable. As discussed in the previous chapter, the difference between these aspects of Forage Habitat may be the result of patch shape, size, and dispersion as well as stand structure. Temporary Non-lynx Areas should therefore be designed to test the effects of these variables on lynx and hare abundance, on both the stand and landscape scales. Even if future research indicates that snowshoe hare are less vulnerable to lynx in high quality Forage Habitat, it is assumed that hare will be vulnerable in the majority of habitats available to lynx in managed landscapes because: 1) most stands provide prime snowshoe hare habitat during a relatively small portion of a rotation (roughly 20 years out of 80), and 2) not all Temporary Non-lynx Areas will grow dense enough to produce high quality snowshoe hare habitat. It is therefore likely that high quality sites (where hare are less vulnerable) are the limiting type of Forage Habitat.

3.2.2.1.2 Denning Habitat and Den Sites

This plan recognizes "Denning Habitat" as stands that might support lynx dens such as those reported from northcentral Washington. However, only four dens by two females have been located (Koehler 1990a). These were on N/NE slopes in mature subalpine fir/Engelmann spruce stands under jack-strawed coarse woody debris. The importance of the old forest and aspect components are not yet understood.

Structure, in the form of debris piles or root tangles, is the common denominator in known den sites when data from other locations are compiled (Table 5, 2.1.3). For this reason, "Den Sites" are recognized in this plan. Den sites represent structures capable of being used by lynx as places to den. A quantified definition of den sites is not currently available but will result from monitoring activities during the first year of this plan (Chapter 6). Until this definition is available, the diameter of structure within den sites will represent the largest material available (WDFW 1996).

3.2.2.1.3 Travel Habitat

All other forested habitats that do not fall into the specific categories of "Denning Habitat" or "Forage Habitat" are referred to as "Travel Habitat" in this plan. These habitats will maintain at least 180 tpa that are at least 3.3 feet above snow level, or have at least 70% canopy cover in stands of mature timber with branches between 4 and 8ft above ground. This habitat category may be important for providing lynx with access to alternative prey, cover during inclement weather and from predators, and/or to connect denning and forage habitat.

3.2.2.2 Temporary Non-lynx Areas

Temporary Non-lynx Areas arise from wildland fire, clearcuts, or partially harvested stands (<180 tpa, <3.3 ft or 1m tall). It is the potential of these areas to grow into forested lynx habitat that separates these areas from the Open Areas described previously. They are therefore included as lynx habitat, whereas Open Areas are not. Although lynx temporarily avoid Temporary Non-lynx Areas as they do Open Areas, a complete description of lynx habitat must include Temporary Non-lynx Areas in enough quantity to continually maintain hare habitat. Because forests are constantly growing out of the reach of hare, forest managers must risk temporary evacuation of lynx and hare remaining in mature forests to renew succession and ensure the continued presence of hare in enough quantities to facilitate successful reproduction in lynx. This inverse relationship is the lynx habitat paradox, and will be detailed in the next section.

Meanwhile, Temporary Non-lynx Areas are indicated by light brown shading on the maps within this plan (Fig. 6). The color of shading and name "areas" (vs. "habitat") were selected to emphasize the similarities of Temporary Non-lynx Areas to Open Areas, but the category is listed in the map legends as Lynx Habitat to indicate potential Forested Habitat status.

3.2.3 Travel Routes

Given the presence of Temporary Non-lynx Areas and Open Areas within landscapes used by lynx, a need for a final habitat component arises. This component is not a separate habitat category; rather, it is a linear feature to indicate potential routes of travel taken by lynx through landscapes that may be composed of any forested habitat category. These "travel routes" (after Koehler and Brittell 1990) follow linear features that already exist in the landscape, such as major ridges, saddles, rivers, and streams. Stable travel routes provide connectivity within the lynx habitat matrix and between habitat elements, facilitating dispersal of kittens and movements of adults. For these reasons, travel routes are important habitat components at all scales of lynx habitat use.

3.3 Developing Habitat Ratios for the LAU's

3.3.1 Quantifying Temporary Non-lynx Areas: the Lynx Habitat Paradox

A key concept in strategies to maintain lynx habitat through time is the lynx habitat paradox: open areas (i.e. Temporary Non-lynx Areas) are required to sustain lynx, but lynx avoid such areas. The paradox is reflected in WDW (1993), a report on the status of lynx in Washington, that cites both lack of hare browse (Forage Habitat) and too little lynx habitat (Forested Habitat) as reasons for the lynx's current status. Ideally, existing individuals can be protected *and* new habitat can be created by using a mixture of techniques and dispersing activity over a large area.

The first source to consult for an appropriate compromise to the lynx habitat paradox is the literature (Table 9). However, by definition, lynx studies have concentrated on habitats used by lynx, which are often ≥80% forested. The vital precursors to hare habitat, early successional or Temporary Non-lynx Areas, are precluded because they are avoided by lynx for the relatively short duration of the study period. For example, at the time the photo in Fig. 7 was taken, lynx inhabited the midsuccessional stand in the center (Johnson et al. 1995), but not the

Table 9: Lynx habitat as quantified in the literature.

Washington (448 mi^2 or 1,161 km^2) Brittell et al. (1989)
Habitat categories within lynx home ranges were not significantly different from those available in the study area (p.31), however "lynx avoid xeric south and west aspects presumably due to the little cover and prey." Smaller lynx home ranges were positively correlated with regenerating forests, mid-elevations, and moderate to low slopes. The study area (**bold**) and mean lynx home ranges contained: **59**-65% forested stands with high canopy closure (>66% closed), **20**-22% forested with medium canopy closure (33-66% closed), and 14-**21**% non-forest. 25 lynx captured, snow tracking indicated others present.

Washington (693 mi^2 or 1,795 km^2) Koehler (1990a)
Lynx "used lodgepole pine and Engelmann spruce/subalpine fir forest cover types in greater proportion than expected and xeric lowland types less than expected." Lowland grassland and ponderosa pine (1.7% mean lynx, 0.3-3.0% range, 15.2% study area), Douglas fir/western larch/quaking aspen (12.8%, 7.8-17.2%, 27.5%), Engelmann spruce/subalpine fir (25%, 15.8-33.8%, 20.6%), lodgepole pine (57.3%, 46.7-65.8%, 31.8%), and alpine meadow (3.2%, 1.3-5.9%, 5%). Lodgepole pine >44yr. covered >80% of the study area; lodgepole <21yr. covered <11%, mainly in 2.5 acre (1ha) plots resulting from lightning and windthrow. Seven lynx were radio collared, two kittens were ear-tagged, and 19 lynx (including 4 kittens) were known to occupy 247mi^2 (640 km^2) of the study area (6.7 adult lynx/100mi^2, 2.6 adults/100km^2).

Ontario (39,376 mi^2 or 107,000 km^2) Quinn and Thompson (1987)
Between "Boreal Mixed Wood" (27% of forest in early successional stages, with 160 ha average clearcut size) and "True Boreal" forests (17% successional, 560 ha avg. size), there were no differences in productivity of lynx or trapping mortality, but the authors speculated that the carrying capacity of Boreal Mixed Wood (southern) forests may have been relatively higher. However, higher but not significant fat levels in lynx but lower lynx density within Boreal Forests suggested that the two forest types were comparable, leading the authors to conclude: "lynx may find prime habitat in disturbed sites in both regions... local wildlife managers believe that distribution of lynx in the coniferous forests is "spotty"; i.e., lynx are relatively sparse but have loci of abundance." (Harvest study-- no lynx density estimated.)

Alberta (50 mi^2 or 130 km^2) Brand et al. (1976)
Densities of 2 - 3 lynx/100 km^2 were reported from a study area described as: "33% improved pasture and cropland; 33% aspen and poplar forest; 15% spruce bog; 8% bog with scattered black spruce, tamarack, bog birch, and willow; 7% brush and regenerating (post-fire) aspen, poplar, and willow; 2% marsh with cattail and bulrush; and 2% open water." (Snow tracking study.)

Kluane, southwestern Yukon (68 mi^2 or 175 km^2) Murray, Boutin, and O'Donoghue (1994)
The study area (contained: 36% open spruce, 25% very open spruce, 16% closed spruce, 2% very closed spruce, 10% shrub, 6% deciduous, 5% open. Lynx avoided shrub and open habitats during all years, selected very closed spruce during low density lynx year (although use always low <11%). Open spruce was most heavily used in all years (35-43%). 10-50 lynx in the larger Kluane Project area (135mi^2 or 350km^2).

Table 9 (*Continued*): Lynx Habitat as Quantified in the Literature.

Cape Breton Island, Nova Scotia (21.3 mi^2 or <58 km^2) Parker et al. (1983:783)
"Optimum lynx habitat on the highlands of Cape Breton Island (Nova Scotia) was represented by a mosaic of approximately 50% mature conifer, 30% mature mixed, 12% successional (~20 years following cutting), and approximately 8% peat bogs, alder swales, and small streams and ponds. We suggest that the amount of successional habitat could have been increased to 20-25% at the expense of the mature mixed type." The authors don't give percent of open habitat, but from a table in the article, home ranges never had more than 15% recent (≥ 4 yr old clearcuts). 3 lynx collared, references to previous snow tracking results.

Kenai Peninsula, Alaska Bailey (1992), letter to Russ Paul
"In general, habitat practices that increase food/cover for hares will benefit lynx and large blocks of good hare/lynx habitat will be better than smaller, separated blocks of good hare/lynx habitat. Your mixture of habitat types for lynx appear reasonable except perhaps for non-foraging or travel habitat. Because lynx are opportunistic, they will take prey anywhere it occurs. Areas of high and low density prey densities better describe lynx habitat in our area, but perhaps good lynx habitat in your area is separated by mountain valleys and developed areas... Our non-lynx habitat only includes lakes and open bogs and roughly approximates about 30% of lynx habitat and home ranges... In mountainous/benchland habitat, conditions appear more like a climax community where hare/lynx numbers are lower but fluctuate less than lowland successional boreal forest. These habitats appear more dependent on hares using alders and willow communities situated in small drainages and slopes/ridges and interspersed with conifers at/near timberline."

Kenai Peninsula, Alaska (92 mi^2 or 250 km^2) Kesterson (1988)
The study area contained: 34.3% mature spruce-hardwood forest (80+ yrs.), 61.4% midsuccessional forest burned in 1947 (38-40 yrs.), and 4.3% early successional forests (8-11 yrs.). Remnant stands of mature forest occurred throughout the 1947 burn (~13 acres), and mature and midsuccessional stands occurred within the early successional areas. "Over 87% of the relocations occurred within the midsuccessional 1947 burn, which occupied 61.4% of the study area. Twenty-four of 101 relocations in mature forest occurred around female den sites... lynx significantly selected midsuccessional forest within the study area and neglected habitats consisting of large expanses of crushed or mature forest." 29 lynx were captured.

Mackenzie Bison Sanctuary, Northwest Territories (112 mi^2 or 290 km^2) Poole et al. (1996)
Landscapes and home ranges used by lynx had high proportions of dense coniferous and dense deciduous forests. Other habitat classes, including open black spruce forests and wetland-lake bed complexes, had lower selection indices. "Much of the dense coniferous habitat resulted from 20-60 year old burns where young conifer and deadfall from fire-killed trees combined to produce dense understory vegetation." Preferred habitat types made up at least 50% of the study area. At least 19% of the study area was shrub, meadow, or water. Another 12% was unclassified. Lynx relocation areas had means of 21-22% unforested habitat types, and mean % unforested habitat in lynx home ranges was 29-28%. 27 lynx were radio-collared.

(Photo taken in 1992 by C.A. Quade.)

Figure 7: A large scale perspective of lynx habitat from the Nowitna National Wildlife Refuge. The foreground area was generally avoided by lynx (7 yrs. post-fire, ca. 54 mi^2 or 140 km^2), the background area was commonly used by lynx (26 yrs. post-fire, ca. 81 mi^2 or 210 km^2), and the central black spruce-dominated mature forest was sometimes used by lynx (ca. 100-115 years old, 2-8" or 5-20cm dbh; Johnson et al. 1995). Traditionally, only the background area is considered lynx habitat. Long-term maintenance of lynx habitat within defined management boundaries requires consideration of all three seral stages as lynx habitat.

foreground burn. However, as the burn grows into Forage Habitat, the pattern of lynx habitat use will change. For long-term maintenance of lynx habitat, both areas need to be included.

Although some information regarding optimum arrangement and quantities of lynx habitat components can be gleaned from the literature (i.e. proportions of habitat types within home ranges), large scale habitat assessments such as those facilitated by GIS have only recently been applied to wildlife studies. Extrapolations of fire history records in combination with aerial photos may currently be the best source of information regarding the shifting availability of lynx habitat components across a landscape through time. However, even this information is largely unavailable for most areas inhabited by lynx.

Most average lynx home ranges probably contain <20% Open Areas/Temporary Non-lynx Areas (Table 9). For example,14% (no range reported) of lynx home ranges were categorized as non-forested habitats in northcentral Washington (Brittell et al. 1989). Together, the information from Table 9 suggests that if 100% of the lynx habitat matrix were to be considered suitable for lynx inhabitation at all times, the extent of open areas within the matrix should probably never exceed 20%.

If the restricting factor of the species were only the loss of forested habitat, lynx recovery in Washington might be achieved by limiting overall loss of forested habitat. However, the current hypothesis is that lynx are limited in Washington due to lack of prey (WDFW 1996). Would a 20% cap on Temporary Non-lynx Areas allow for adequate maintenance of prey habitat? The answer to this question depends on the Forage Habitat ratio, as well as the site conditions and plant associations within the planning area.

3.3.2 Quantifying the Forage Habitat Ratio

From the lynx's perspective, the greater the amount of accessible prey a habitat can support, the better the habitat (habitat quality). Likewise, the more of this habitat available (habitat quantity), the better. Lynx likely encountered wide expanses of ideal habitat in Washington several decades ago, judging by the wide expanse of similarly-aged mature forest that currently exist in places like the Loomis State Forest in northcentral Washington. When these forests were younger and supporting high hare densities, lynx perhaps flourished. Estimates of historical forest conditions based on fire history records in the Methow WRIA (Table 10) also suggest periodic dominance of prime hare/lynx habitat in the landscape.

Of course, historical disturbance regimes may not be a valid base for extrapolation given the social and ecological context surrounding forest management within lynx range. Air and water quality, recreation, mineral extraction, livestock grazing, and timber harvesting are social concerns that generally demand gradual change rather than the "boom or bust" change of the past.

Table 10: Historical landscape composition of watersheds in the Methow River Basin estimated from recent fire history records (adapted from U.S.F.S. 1993: 91).

Structural Stage	**Primary Species**	
	Lodgepole Pine	Engelmann Spruce/ Subalpine Fir
Early even aged, from seedling/sapling to small saw timber, lacking understory	27-45%	15-24%
Middle bilayered with 1) shade tolerant understory species in seedling/sapling or small pole; and 2) saw timber and larger overstory	35-74%	42-89%
Late understory is codominant to dominant and occupies all canopy layers as overstory declines; standing and down debris are mostly small to medium sized but some large trees have recently died and are becoming snags	5-11%	10-22%
Old considerable stem decay and top breakage visible in overstory, many seral trees have fallen; the former understory has replaced the original overstory, so that the stand is characterized as having an overmature seral overstory	0.7-1.3%	0.7-1.3%

Even without the above concerns, lynx recovery could not be guaranteed if the historical disturbance regime were applied today. The presence of lynx and other species is the combined result of many variables and circumstances that have likely all changed to some extent since the last extensive disturbance event. For example, the total land base available for lynx habitat in Washington is decreasing and disconnecting due to human development (e.g. Methow valley) and resource extraction activities (WDW 1993). It is not known how much habitat of what quality is required to maintain a persistent lynx population. Also, development and resource extraction has occurred in neighboring lynx habitat, reducing the potential of these populations to produce dispersers that might historically have repopulated lynx habitat after disturbance. Lastly, formerly remote areas are increasingly susceptible to human disturbance due to the popularity of snowmobiles and all-terrain vehicles. Disturbance within lynx habitat may reduce the quality of current vs. past habitat, which may therefore be reflected in the area's potential to support lynx. In conclusion, something less drastic than historical disturbance patterns is likely necessary to sustain lynx under today's habitat and social constraints.

Meanwhile, the Forage Habitat ratio should reflect the quantity and connectivity of habitat elements necessary to maintain a high enough density of hares over a large enough area to enable lynx to reproduce successfully. A starting hypothesis is to achieve some median density of hares (i.e. >1.0 hares/ha)[19] over a median female Washington lynx home range (i.e. 16 mi^2)[13] for a median time period (i.e. 4-5 yrs. out of every 8-11 yrs., Brand et al. 1976). However, our current understanding of lynx habitat relationships is not sophisticated enough to broadly apply such a strategy. Instead, we must extrapolate from what is known and adapt management strategies to new information as it arises.

The information available for extrapolation is far from adequate, but can result in an initial hypothesis. Research in Washington (Koehler 1990a) indicates that landscapes with <10% Forage Habitat (20 yr. old lodgepole pine) may not support successfully reproducing populations of lynx. Similarly, hares occupy only 10-18% of available habitat during hare lows in Alberta (Keith 1966, Keith and Windberg 1978) and Alaska (Wolff 1980) (2.2.2), and lynx do not reproduce successfully during hare lows (1.1.3). Given that predation pressure on hares is at least as high in southern latitudes as northern latitudes, Forage Habitat should perhaps meet or exceed 20% of the landscape to increase the probability of successful recruitment in lynx. This hypothesis is supported by Parker et al. (1983), who speculated that lynx landscapes in Nova Scotia should contain 20-25% ~20 year old stands.

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[19]For example, lynx abandoned their home ranges or died of starvation when hare density was 0.4-1.0 hares/ha in Northwest Territories (Poole 1994), lynx became nomadic when hare density was <0.5 hares/ha in the Yukon (Ward and Krebs 1985), and lynx abandoned home ranges when hare density was <1.0 hare/ha on the Kenai Peninsula (Kesterson 1988).

3.3.2.1 Introduction to the Lynx Habitat Ratio

The Lynx Habitat Ratio (LHR) is a simple index that relates the benefits of Forage Habitat to the costs of Temporary Non-lynx Area, by dividing the time a stand spends as Forage Habitat by the time spent as Temporary Non-lynx Area. High LHR indicate favorable conditions for lynx. For example, if a stand re-seeds one year after clearcutting, takes 11 years to grow into Forage Habitat, and spends the next 24 years as Forage Habitat, the Lynx Habitat Ratio is 2.0 (24/12). If a different stand is planted two years after clearcutting, takes 8 years to grow into Forage Habitat, and spends the next 12 years as Forage Habitat, the Lynx Habitat Ratio is 1.2 (12/10). Comparing these two stands, the LHR=2.0 stand has higher value to lynx than the LHR=1.2 stand, because it offers more Forage Habitat for a lesser cost of time spent as Temporary Non-lynx Area. The LHR will be used below to explore the relationship of the habitat ratios developed so far.

3.3.2.2 Influence of Plant Association on Forage Habitat Ratios

Sites within lynx range have different capabilities of producing Forage Habitat, based on the specific growing conditions of the site. The ability of landscapes to meet a minimum 20% Forage Habitat ratio given a 20% maximum limit on Temporary Non-lynx Areas therefore depends on growing conditions within the landscape. In areas dominated by vegetative associations with high Lynx Habitat Ratios, 100% of the area might be available for occupancy by lynx. Because the plant associations facilitate maintenance of Forage Habitat at little cost of Temporary Non-lynx Area, a minimum of 80% Forested Habitat and maximum 20% Temporary Non-lynx Area could be present while still maintaining the Forage Habitat Ratio (Fig. 8).

Landscapes dominated by stands with low LHR (<1, Fig. 8) may not be able to meet the minimum Forage Habitat ratio of 20% given the Temporary Non-lynx constraint. Assuming that 20% Forage Habitat is an appropriate minimum estimate of what is needed by lynx for successful recruitment, landscapes that cannot meet this ratio would therefore not be able to contribute to the recovery of lynx in Washington. Recruitment in lynx is closely tied to snowshoe hare density (1.1.3), and snowshoe hare habitat (Forage Habitat) is the current limiting factor of lynx in Washington (WDFW 1996).

Alternatively, the quantity of acceptable Temporary Non-lynx Areas could be increased in landscapes that are less efficient at maintaining Forage Habitat so that the minimum 20% ratio is in reach. This would require a compromise of total forested habitat available to lynx. For example, if the Temporary Non-lynx Area limit were increased to 30% maximum, only 70% of the LAU would be available for occupancy by lynx as forested habitat. The compromise would be reduced habitat availability (10% of the area) for increased probability of supporting successful reproduction in lynx.

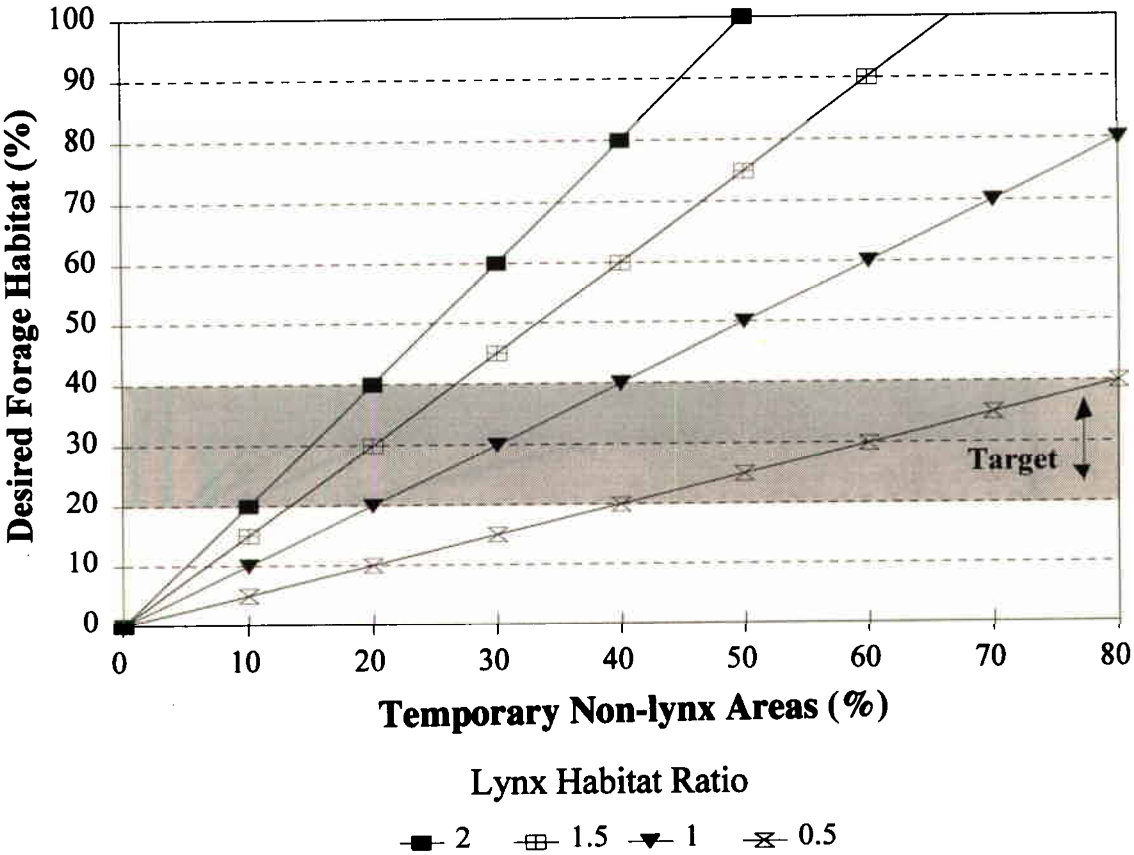

Figure 8: The proportions of Temporary Non-lynx Areas required to produce various proportions of Forage Habitat according to Lynx Habitat Ratio. Ratios were derived from those available in the Okanogan LMZ (Table 12), but this range of values is also appropriate for the vicinity of Colville National Forest (J. Hallet, Wash. State Univ., pers. commun.).

Raising the Temporary Non-lynx Area limit to 30% (maximum) of a landscape suggests that landscapes with average LHR >0.67 would still be able to meet the minimum 20% Forage Habitat ratio (Fig. 8). Stands with LHR below this threshold may bypass the Forage Habitat stage, growing from Temporary Non-lynx Areas straight into Travel Habitat. Allowing up to 30% maximum Temporary Non-lynx Area per LAU would minimize the total impact of these stands and others that are too sparse to be considered Forage Habitat (i.e. regeneration mistakes) on the proportion of Forage maintained within the LAU. Landscapes managed for lynx in Washington are generally large enough to accommodate female lynx home ranges in 70% of the area to be managed (median LAU = 31.6 mi^2 or 82 km^2 vs. median female lynx home range = 14 mi^2 or 36 km^2; 1.4.2).

3.3.2.3 Managing the Lynx Habitat Ratio

The potential deficit of Forage Habitat that might result when LAU's contain high proportions of plant associations with low LHR's illustrates the potential of active management to improve lynx habitat through manipulation of the Lynx Habitat Ratio. Land managers may be able to prolong the hare's use of some stands by employing thinning and understory manipulations. This could be especially useful if some stands or associations do not regenerate as quickly as planned.

Consider an example based on the Loomis State Forest. Vegetative associations occurring within lynx range on the Loomis State Forest are grouped in Table 11, as adapted from the USFS (1993) and Envirodata, Inc. (1993) analysis of lynx habitat within the Okanogan National Forest. The groups are described in Table 12, and generally reflect the response of vegetation to elevation with ascending group number. The effects of three silviculture treatments (control, early, and late) on the groups were modeled using PROGNOSIS (Fig. 9). Thinning improved the LHR of three out of the four groups, dramatically improving forage conditions in Group 3 (LHR = 1.2 to 2.0), characterized as having moderate growth rates and densities. As might be expected, thinning had detrimental effects on Group 1 (LHR = 2.0 to 0.47), characterized as containing slow growing and low density associations. The latter example illustrates the need for caution when applying thinning regimes to adjust LHR's.

The potential usefulness of active management can be explored by extrapolating the habitat proportions identified in Fig. 9 (based on a 70 year rotation) to the quantity of each vegetative association occurring within the Loomis State Forest (1993 DNR inventory data; Fig. 16, Chapter 4). By applying the most effective (highest LHR) treatment for each group of associations (Fig. 9), increases in Temporary Non-lynx Area proportions of 2% (North LAU), 3% (Central LAU), and 1% (South LAU) resulted in an additional 14% (North LAU), 11% (Central LAU), and 8% (South LAU) Forage Habitat per LAU, respectively (Fig. 10).

Table 11: Plant associations, common names, and group for creating Forage Habitat.*

Plant Association	Common Name	Group
PIPO-PSME/AGIN	ponderosa pine-Douglas fir/beardless bluebunch wheatgrass	0
PSME/ARUV-PUTR	Douglas fir/bearberry-bitterbrush	0
PSME/SYOR	Douglas fir/mountain snowberry	0
PSME/SYAL	Douglas fir/common snowberry	0
POTR/CARU	quaking aspen/pinegrass	0
PSME/ARUV	Douglas fir/bearberry	1
PSME/CARU	Douglas fir/pinegrass	1
PSME/VACCI	Douglas fir/huckleberry	1
ABLA2/VASC/CARU	subalpine fir/grouse huckleberry-pinegrass	1
ABLA2/CARU	subalpine fir/pinegrass	2
ABLA2/LIBOL	subalpine fir/twinflower	2
ABLA2/PAMY	subalpine fir/pachistima	2
ABLA2/VACCI	subalpine fir/huckleberry	2
ABLA2/RHAL	subalpine fir/Cascade azalea	3
ABLA2/VASC	subalpine fir/grouse huckleberry	4

*Adapted from Envirodata Systems, Inc. (1993) and Williams and Lillybridge (1983).

Table 12: Characteristics of plant association groups.*

Group Number	Site Index (Range)	SDI (Range)	Lynx Hab. Ratio	Characteristics
0	38-100	93-310	?	generally sparse, primarily S-W-E aspects
1	32-45	276-290	2	slow growth, low density, E-W-S aspects
2	46-50	376-443	1.4	fast growth, high density, all aspects
3	35	384	1.2	moderate growth and density, N aspect
4	31	417	1.1	slow growth, high density, all aspects

*Adapted from Envirodata Systems, Inc. (1993) and Williams and Lillybridge (1983).

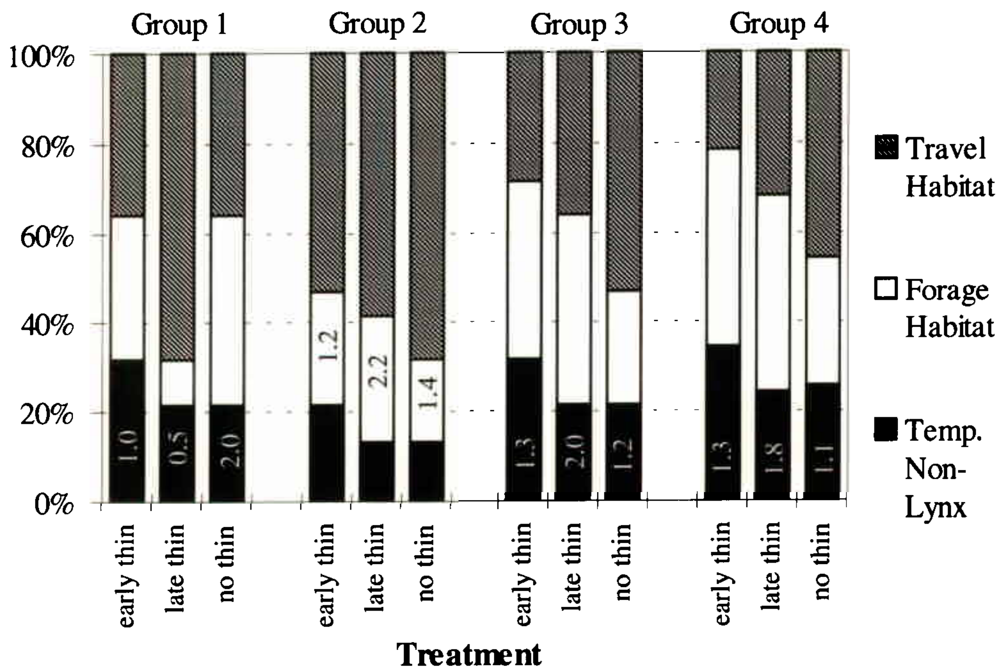

Figure 9: Time (over a 70 year rotation) a stand spends in lynx habitat categories by grouped vegetation associations (Table 11 and 12) and silviculture treatment: early pre-commercial thin to 300-400 tpa (6-8 foot tall trees), pre-commercial thin to 300-400 tpa (13-15 foot tall trees), and no thinning. The number within each bar represents the LHR.

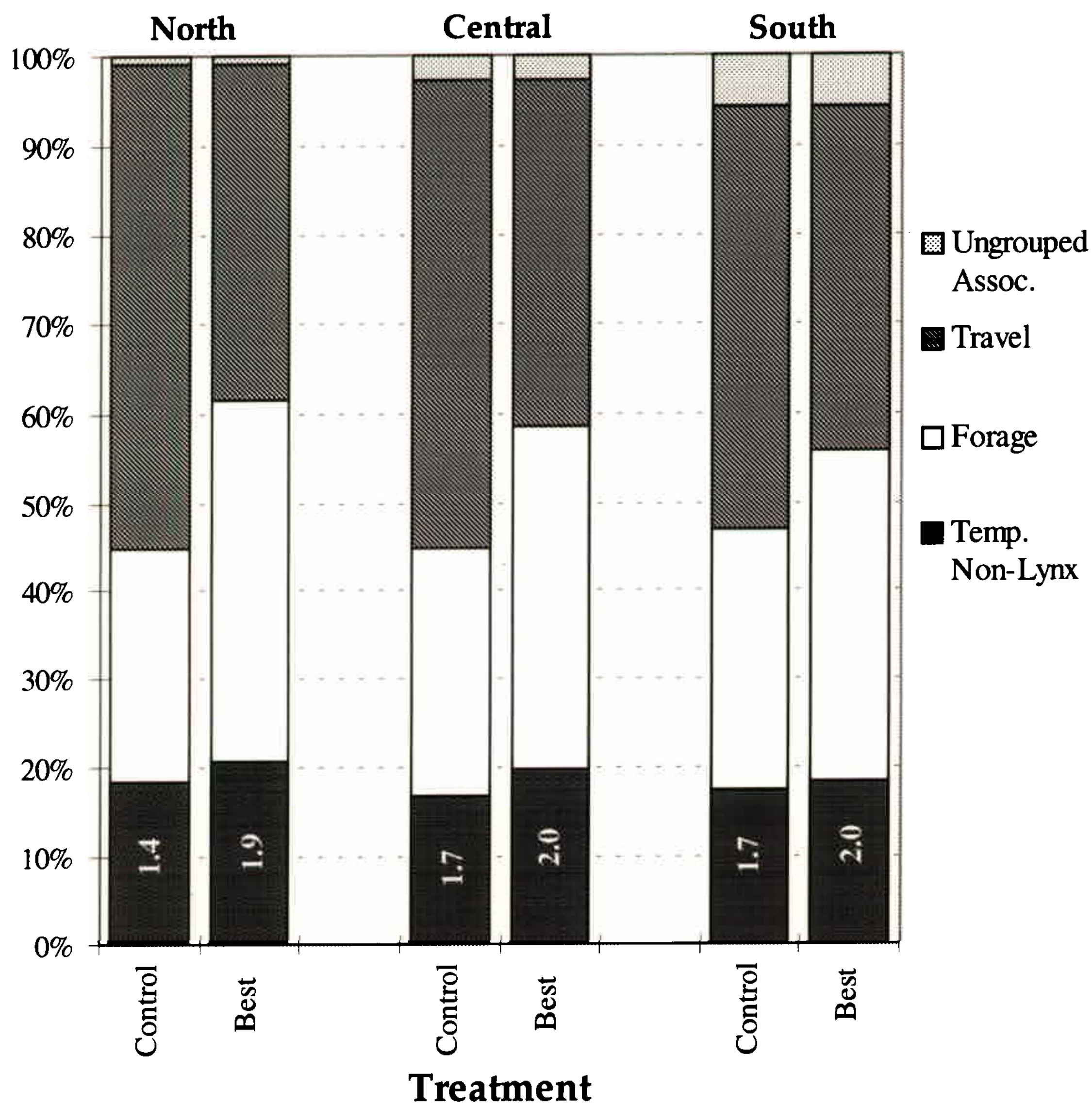

Figure 10: Theoretical proportion of lynx habitat categories available in each LAU of the Loomis State Forest based on the vegetative association groups occurring within each LAU and the optimum treatment (highest Lynx Habitat Ratio) from Fig. 9. The number within each bar represents the LHR.

3.3.2.4 Temporary Non-lynx Area Limits, Revisited

Figure 9 illustrates another interesting point: none of the LAU's appear to require more than 20% Temporary Non-lynx Areas to maintain >35% Forage Habitat. Even without treatments, Fig. 10 suggests that 17-18% Temporary Non-lynx Areas may result in 26-29% Forage Habitat, based on a 70 year rotation (Fig. 9). As more is learned about lynx habitat management, it may be possible to maintain adequate Forage Habitat within each LAU without compromising habitat availability (i.e. the 10% described above). However, it is doubtful that all harvest units will regenerate as modeled to the density needed for Forage Habitat, due to the many site specific factors that influence regeneration. Setting the Temporary Non-lynx Area limit to 30% maximum per LAU should accommodate some overestimation of Forage regeneration and yet still promote enough Forage Habitat to provide lynx with prey for successful reproduction.

3.3.2.5 Cautionary Note

Although the preceding theoretical analysis is useful for developing habitat ratios and for illustrating potential silviculture tools, it is imperative to emphasize the hypothetical nature of the ratios and tools both in terms of vegetation and animal response. Management activities within lynx range must be considered "experiments" that include careful planning and monitoring for vegetative response and lynx and hare recovery. For example, one hypothesis could be that the computer model accurately depicts the effects of thinning on the LHR of various vegetation associations. A set of stands within each group could be thinned according to the modeled treatment schedule and monitored for vegetation and hare response. Such "experiments" will lead to more efficient management strategies, that incorporate both habitat quantity and quality. Additional plant associations could also be modeled and monitored to aid planning efforts, especially from the eastern LMZ's. Landscape level research will be required to test the response of lynx to the habitat ratios. This might involve correlating habitat change using GIS to an index of lynx use (i.e. lynx density, home range size, presence of kittens, etc.).

3.3.3 Quantifying the Denning Habitat Ratio

Although Denning Habitat is generally not limiting in other areas within lynx range (2.1.3), the threatened status of lynx in Washington and lack of information demand a conservative approach to Denning Habitat management. The difficulty is that this habitat type takes a relatively long time to develop. If the extent of these older forests is substantially reduced in the landscape and future research reveals that this habitat is more important than originally suspected, it may take many decades before the habitat is again suitable for lynx. The philosophy in this habitat management plan is therefore to designate denning habitat based on what *is* known about lynx dens in Washington, and to make adjustments in the future as necessary.

The 10% minimum Denning Habitat ratio recommended in this plan follows WDFW (1996). This proportion falls within the ranges historically occurring within the Methow River Basin (Table 10), if Denning Habitat includes both "late" and "old" structural stages. The same is probably true for landscapes in the eastern LMZ, where the cooler, moister forests burn at a slower interval (4.2). Even if an entire LAU were subject to wildland fire in a worst-case scenario, the proportion of area left unburned within the fire perimeter might be near 5% (using median LAU size of 32 mi^2 or 82 km^2; 1.4.2), as extrapolated from a study on large fires in Alberta (Eberhart and Woodard 1987).

Within the 10% minimum Denning Habitat per LAU, lynx may find thermoregulatory benefits and/or alternative prey opportunities (2.1). Alternative prey may be especially important in the southern latitudes of lynx range where hares tend to maintain lower densities and there are more competing predators. More research on the habitat needs of lynx will be needed to decipher the importance of mature forests and the definition and role of denning areas in Washington.

Meanwhile, the substantial information indicating the importance of structure to and dispersion of denning sites (Table 5) led to the den site dispersion guideline (Guideline 10) below. Lynx may use more than one den site when denning habitat is abundant (summary, Koehler and Aubry 1994). Dispersing a number of suitable den sites within a short radius of each other may increase the survival of kittens because the female will be able to minimize the time the kittens must be left unprotected while she hunts for prey for them.

3.4 Guidelines and Ratios

(Note: a condensed version of the ratios and guidelines is provided in Appendix B).

1. *Ecoprovinces and Ecodivisions.* A system of travel routes will be maintained along major ridges, saddles, and streams to connect DNR-managed lands with neighboring lynx habitat and to provide access to drainages throughout the LMZ. The system was drawn from topographic maps to provide a travel network across each LAU (Fig. 11), reflecting lynx habitat use patterns as indicated from the WDFW PHS database. These routes will be field-verified to ensure that the most suitable routes are chosen. A special management zone [travel *corridor*] will straddle the route so that a ≥330 feet (100m) corridor (WDFW 1996)[18] is available to lynx at all times. On average, the forested zone along the travel route will likely be much wider (Fig. 12).

The primary habitat concern at this scale is connectivity (Table 2). In particular, the travel route system attempts to address: 1) adult movements associated with breeding activities, 2) juvenile movements associated with dispersal, and 3) individual movements associated with periodic fluctuations in prey density. These movements may result in critical genetic exchange among populations (1.4.2.1).

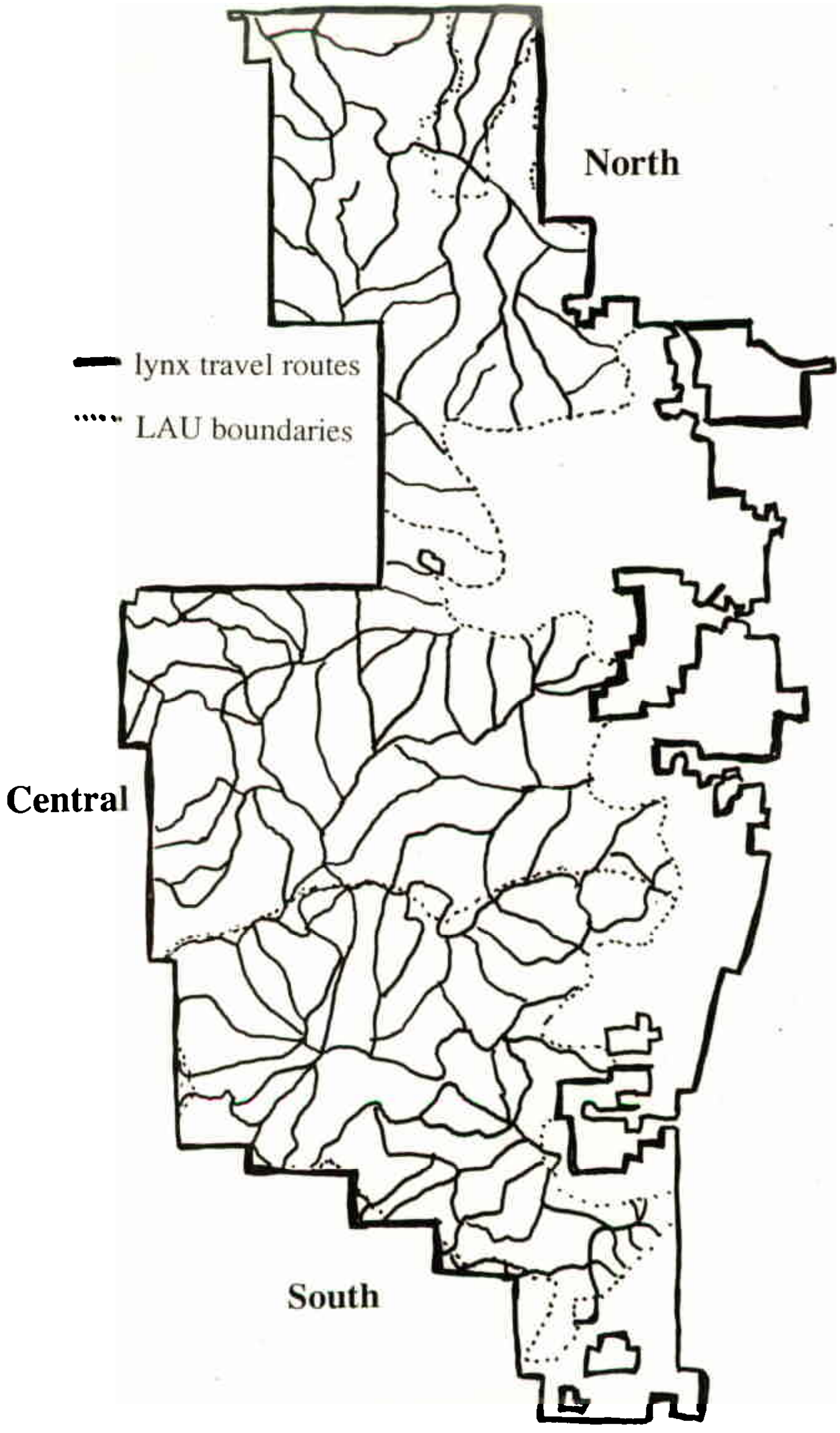

Figure 11: Travel routes identified for three LAU's in the Loomis State Forest. Routes were chosen from topographic maps to provide a network of connectivity across the area.

a. Sample initial harvest design:

b. Second phase (>15 years later):

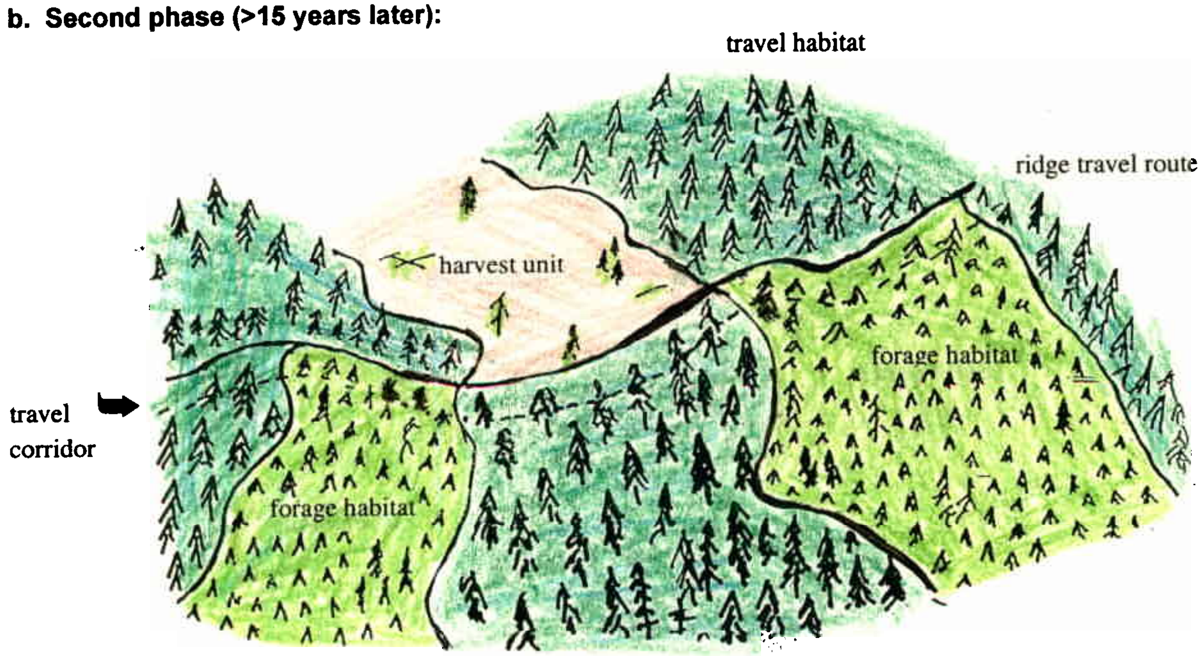

Figure 12: Sample travel route system and management over two phases (a, b).

None of the movements are necessarily associated with the habitat quality of a particular LAU. For example, resident lynx avoid poor habitat when possible, but non-resident lynx might easily cross several LAU's and many different habitat types during long distance dispersal events (B. Slough, Yukon Dep. Renewable Resour., pers. commun.). Travel routes along features that naturally connect landscapes, such as ridges and streams, will facilitate dispersal across jurisdictions and without regard to the habitat quality within a LAU. Forested conditions along the routes may enhance the security of dispersing lynx and increase the probability of successful dispersal.

The most important ridges, saddles, rivers, and streams are those that contribute to the overall connectivity within the LMZ. These features influence lynx home range boundaries and movement patterns (Parker 1981, Koehler and Aubry 1994). Minor rivers and streams, ridges and saddles, "dead end" ridges and saddles, and duplicate ridges and saddles can be incorporated as possible alternate routes.

Lynx in northcentral Washington often travel on ridges and saddles (Koehler 1990a). On the Loomis State Forest (Okanogan Zone), 30/100 occurrences (WDFW PHS database) were in such areas. Lynx on the Kenai Peninsula, Alaska, similarly traveled on ridges (highest route near forage areas): 45.9% of 38 miles (61 km) of lynx tracks followed were on the "top of sharply defined ridges" (Staples 1995:63). This association to ridges and saddles seems intuitive for a number of reasons: 1) these areas may be easier to walk through than lowland forests because tree density is often limited by harsh climatic and/or soil conditions (Kenai Peninsula: these areas were often unburned and so therefore contained mature trees and relatively open forest, Staples 1995), 2) it may be easier to spot patches of prey habitat from elevated areas (lynx often sit on ridges and peer down slope into hare habitat, Staples 1995), and, 3) light conditions may be more advantageous (twilight) for longer periods than in the shaded valleys. Also, Staples (1995) suggested that lynx may find fresh carrion by traveling on ridges where they can see ravens and eagles roosting from long distances 0.6 mile (1 km).

Lynx have also been known to travel and hunt along riparian zones (Major 1989; K. Poole, Northwest Territories Dep. Renewable Resour., pers. commun.), although only 1.1% of trail segments of tracked Kenai lynx were located in low draws (Staples 1995). In southern areas of snowshoe hare range, it is likely that riparian areas become more important habitat elements due to their favorable microclimate and ready supply of browse. Guidebooks from southwestern areas of hare range commonly list riparian and boggy habitats as favored snowshoe hare habitat (Ingles 1965, Kurta 1995). Therefore, maintenance of forested areas along these geographic features may contribute to the connectivity of lynx habitat.

a. Actual boundaries of the travel corridor along the travel route will reflect the existing contours of the landscape.

Lynx often hunt ridge lines by "zig-zagging while moving parallel to the long axis of the terrain feature" (Staples 1995:64).

b. Where the travel route is naturally forested, Forested Habitat conditions will be encouraged within the travel corridor.

Given the lynx's tendency to avoid open areas (2.1.4), forested travel routes are likely preferred. However, considering the incredible distances traveled by dispersing lynx (>300 miles or 500-1,100 km, Slough 1995), it is likely that at least some portions of routes traveled are relatively open. On the Loomis State Forest, the majority of ridge occurrences of lynx were nonetheless on forested areas (77%, 23/30 forested). However, open ridges may be important to resident lynx during periods of prey scarcity, as indicated by observations of lynx hunting high elevation open habitats for hoary marmots and Columbian ground squirrels in Montana (Glacier National Park, Barash 1971). Maintaining forested conditions where possible will provide lynx with cover during dispersal.

c. If harvest activities must occur within the travel corridor along a ridge or saddle travel route, openings will be minimized (less than 330 feet or 100m wide), techniques to ensure regeneration will be employed, and forested areas will be left on lower slopes and on the other side of the ridge/saddle to provide lynx with alternative travel routes (Fig. 12). Also, the context of the zone will be considered, so that an appropriate amount of cover will be left within the corridor.

Ridges and saddles are difficult to regenerate due to their increased exposure. Alexander (1973) reported that spruce-fir forests have very high susceptibility to windthrow on saddles and ridges. Gaps on forest ridges should be kept ≤330 feet (100 m) wide because lynx in northcentral Washington avoided crossing open areas >330 feet (100 m; Koehler 1990a, Staples 1995). However, such gaps at higher elevations are also known to funnel winds, which further increases windthrow risk (Alexander 1973). Given the importance of these areas to lynx and the high risks of regeneration failure, the preferred solution is to avoid harvest within them.

If regeneration and blowdown risks are minimal, part of a ridge or saddle could be harvested (Fig. 12), if ≥330 feet (100 m) wide corridor of forested cover is maintained on the opposite side of the ridge/saddle and/or there are alternative routes that lynx could use to travel through the area. In such cases, the context of the travel route will be considered. For example, if the route is situated in an area dominated by Open Areas or Temporary Non-lynx Areas, cover within the travel corridor may be critical. Therefore, harvest that reduces cover will be avoided and the corridor left for lynx will contain the maximum cover available on the site. If the route is situated within Forage Habitat, a more open corridor would be desirable (allowing ease of travel and hunting along the forage habitat edge, such as the unburned remnants within the Kenai Peninsula burn, Staples 1995), and therefore harvest that reduces cover might be planned.

d. If roads must be placed on ridges or saddles due to concerns such as slope stability or water quality, road width will be minimized, vegetative cover will be encouraged on both sides of the roads, sight distance will be reduced (330 feet or 100m), and/or the roads will be closed as soon as possible, or at least the frequent use of such roads will be discouraged.

Koehler and Brittell (1990:13) summarized lynx concerns over road issues and stated, "lynx frequently travel along roads with less than 50 foot right-of-ways, where adequate cover is present on both sides (of the road)." Parker (1981) noted that lynx readily followed road edges and forest trails on Cape Breton Island, Nova Scotia.

However, Staples (1995) reported that lynx "usually crossed roads at a right angle and did not use or follow roads for long distances." Brocke (1990) recorded high numbers of road-killed lynx during a reintroduction program in the Adirondacks. Lynx were vulnerable because of the 1) large distances traveled and 2) the attraction of lynx to hares, and hares to roadside vegetation. Staples (1995) also noted that lynx fed on carcasses along roads. Furthermore, indirect negative effects of roads such as poaching, accidental hunting, incidental trapping, vehicle collisions, and competition with other predators that favor roaded systems may pose a serious threat to lynx (G. Koehler, WDFW; B. Ruedigger, Northern Reg. USFS; W. Staples, Univ. Alas., Fairbanks; J. Weaver; pers. commun.; Brocke 1990). See Guideline 5 below.

2. *Lynx Management Zones*. Connectivity within LMZ on DNR-managed land will be maintained. Where DNR-managed land is in a critical position (i.e. a narrow constriction within the LMZ, especially along the British Columbia border), forested strips ≥330 feet (100m) wide will be positioned to facilitate lynx travel through the area, and/or harvest units will be placed to promote connectivity. This may entail keeping harvest units narrow, small, and/or dispersed.

Refer to 2.1.4 and "*Ecoprovince*"guidelines, above.

3. *Lynx Analysis Units*. The following ratios of lynx habitat components will be maintained in each LAU on DNR-managed lands where DNR manages 20% or more of the LAU (Loomis State Forest and Little Pend Oreille Block). Refer to Table 8 for definitions of habitat categories. The percentage ratios are based on the total acres of potential forested lynx habitat per LAU (total LAU acres minus permanent natural openings and sparsely forested areas).

Lynx Habitat:	**Forested Habitat**[20]	70% minimum
	Temporary Non-lynx Areas	30% maximum
Within Forested Habitat:	**Forage Habitat**	20% minimum
	Denning Habitat	10% minimum
	Total den sites	min. 2 sites/mi^2

(See 3.3 for development of habitat ratios. See Guideline 8 for description of den sites.)

[20]Open Areas (sparsely or non-forested land) was subtracted from the acres to be evaluated quantitatively, because such areas are generally avoided by lynx, regardless of harvest activity, and can therefore never be managed to support forested lynx habitat (2.1.4).

4. *Lynx Analysis Units.* Timber harvests will incorporate interspersion of habitat components within the lynx habitat matrix where DNR manages 20% or more of the LAU (Loomis State Forest and Little Pend Oreille Block).

a. Forage Habitat will be connected to travel routes with Forested Habitat within the LAU and located near Denning Habitat (<3 miles or 4.8 km).

Proximity of Denning Habitat to Forage Habitat is critical (2.1.3 and Table 5). WDFW (1996) suggested that forage habitat should be within 0.5 mile of Denning Habitat. Koehler (1990a) hypothesized that the low survival of kittens in northcentral Washington was related to and reflected in the large distances that two denning females traveled to reach forage habitat (up to 4.3 mile or 7 km).

b. To avoid isolation of Denning Habitat, more than 50% of the periphery of Denning Habitat will be bordered by Forested Habitat at all times.

Because lynx do not cross large openings (2.1.4), surrounding Denning Habitat with harvested units may temporarily nullify its use by lynx. Brittell et al. (1989) hypothesized that 50% of the border of Denning Habitat should be Forested Habitat (no dens were found in the study).

5. *Lynx Analysis Units.* Human-related disturbance will be minimized with road and harvest plans where DNR manages 20% or more of the LAU (Loomis State Forest and Little Pend Oreille Block). Examples include rehabilitation of non-essential roads after harvest, gate placement to limit vehicular access (including snowmobiles), and avoidance of loop roads.

Because lynx are often described as "curious" (Jackson 1961), "playful" (with feathers and other objects; Saunders 1961, Halfpenny and Biesiot 1986), and perhaps indifferent to human activity (indicated by sightings in garbage dumps, residences, and camps; Halfpenny and Biesiot 1986, van Zyll de Zong 1966, Staples 1995), they are susceptible to trapping, road kills, and other sources of human-related mortality. Staples (1995) reported that lynx did not flee in 92/105 instances when they were encountered by humans at close range. As stressed by T. Bailey (Kenai Natl. Wildl. Ref., pers. commun.), "I would recommend that every effort be made to minimize human-caused lynx mortality until the prey base and habitat quality significantly improves in your area of concern and you have definite indications of increased kitten production and survival." This will necessitate minimizing road density, avoiding loop roads, replanting/destroying unused roads, gating less frequently used roads, limiting sight distances on roads when possible, maintaining vegetation on the shoulders of roads (Koehler and Brittell 1990). Roadless logging techniques should also be considered where feasible.

6. *Small Ecosystem/Ecological Communities.* Harvest units (Temporary Non-lynx Areas) will be designed to promote swift vegetative regeneration and snowshoe hare/lynx recolonization.

As described in Chapter 2, snowshoe hare habitat contains three elements at the stand level: 1) food in the form of small diameter stems, needles, branches, and bark of shrubs and conifers, 2) winter cover in the form of conifers and/or deadfall/slash/blowdown, 3) interspersion of open habitats with densely covered habitats in the form of gaps in a dense midsuccessional forest or clumps of dense vegetation within open forests. The definition of Forage Habitat in Table 8 is simplified to reflect the hare's winter habitat needs, the season when hares are most vulnerable (Trostel et al. 1987, 2.2.4). The following list of guidelines should be combined and updated with the "Lynx Habitat Field Notebook" currently being prepared by the Washington Interagency Lynx Committee.

a. Unit size will reflect the regeneration capacity of the site and contribute to a diverse mosaic of habitat patches available to snowshoe hare and lynx. Units will be designed so that Temporary Non-lynx Areas never exceed 200 contiguous acres (81 ha; see also 5.1.1). Where DNR manages more than 20% of a LAU, the total Temporary Non-lynx Area per LAU on DNR-managed lands is limited to 30% [3].

Conroy et al. (1979) suggested that the distance from newly cleared harvest units to cover should not exceed 656 - 1,312 feet (200-400 m) to benefit snowshoe hare and regeneration. Koehler and Brittell (1990) recommended unit sizes less than 40 acres (16.2 ha) to encourage natural regeneration. However, regeneration is site-specific and a variety of harvest unit sizes might provide a better mosaic of habitat for lynx and hare, due to the effects of patch size and spatial relationships on hare densities. For example, small populations within12-17 acre (5-7 ha) sites did not persist as long as larger populations in 56-69 acre (23-28 ha) sites in Wisconsin (Keith et al. 1993). J. Thomas and J. Hallett (Wash. State Univ., pers. commun.) also found higher densities of hares in large patches than small patches in the Colville Natl. For.. It is possible that the interior of larger patches provides a refuge for hares, enabling them to persist through periods of intense predation (see "b" below). Small units also necessitate frequent human disturbance and road access, both of which are thought to be detrimental to lynx persistence (Koehler and Brittell 1990; Guideline 5).

In recent history (early 20th century), the mean patch size of lodgepole pine in age classes preferred by hare and lynx averaged 155-185 acres in the Methow Valley (Lemkuhl et al. 1994). Areas up to 170 acres (median of the Methow range) in similar age classes might be therefore appropriate for the lynx landscape, if the large size of the unit didn't impair regeneration within the stand. Adding for variability (only means were reported), up to 200 acres is a hypothesized upper limit, provided that these larger units do not dominate the landscape. Occasional larger sized patches might benefit lynx indirectly by reducing the traffic on roads and the total amount of roads needed, as well as addressing the prey vulnerability/abundance issue.

Given the uncertainties and issues detailed above, a combination approach to unit sizes is appropriate. Such an approach offers opportunity for recovery if the management experiment fails. For example, the combination might include: 1) larger cleared units (e.g. 100 acres), so that hare have refugia and a chance to reach higher numbers, and 2) similarly sized areas (e.g. 100 acres) with small, grouped harvest units (20-40 acres) separated by forested corridors, to favor hare vulnerability for lynx.

b. Unit shape will enhance the regeneration potential of the unit and provide a diversity of forage and browse opportunities for the lynx and hare.

Periodic constrictions of 330 feet (100 m) or less within harvest units are recommended to provide lynx with opportunities to cross larger units (Koehler and Brittell 1990).

A combination of unit shapes is recommended. Research in other southern areas of snowshoe hare range (i.e. Wisconsin: Buehler and Keith 1982, and Sievert and Keith 1985) suggests that hares may be most vulnerable along edges. Lynx are capable of hunting both within and along the edges of thick stands that hare prefer (Murray et al. 1994), but coyotes (Theberge and Wedeles 1989)[21] and avian predators mostly hunt the edges. Maximizing edge may therefore increase the vulnerability of hares to the latter, at a net cost of hares needed by the lynx. Also, a policy of maximizing edge will increase the amount of browse that snowshoe hares must share with browse competitors such as domestic sheep (Dodds 1960), moose (Dodds 1960, Oldemeyer 1983), white-tailed deer (Bookout 1965), and perhaps domestic cattle (suggested for other leporids by MacCracken and Hansen 1989). Snowshoe hare browse grass and other herbaceous vegetation during the snow-free season (Brooks 1955, Severaid in de Vos 1964, Wolf 1978, Hik 1994, Nams et al. 1996). Because large ungulates might have less influence on the interior of a dense stand, relatively more forage would be available to hares if the area to perimeter ratio were larger.

If enough hares and hare browse are available in the landscape, both browse (hare vs. ungulate) and prey (lynx vs. other predators) competition may be ameliorated. For example, Witmer and DeCalesta (1986) attributed the coexistence of bobcat and coyotes in a managed forest to high prey abundance (both species consumed mainly mountain beaver).

c. Unit composition will enhance the regeneration potential of the site and provide opportunities for rapid hare recolonization by containing clumps of remnant vegetation and/or woody debris.

Standing trees or snags, shrubs, and slash can be important sources of seed within lodgepole pine harvest units (Lotan and Perry 1983). Leaving such structure behind may mimic moderate intensity wildfire that generates prime lynx habitat. Hare use within clearcuts was higher than expected in uncut, non-merchantable clumps within clearcuts such as islands, riparian zone buffers, and wetland buffers (Monthey 1986). Compared with sites not used by hares, occupied managed forest habitat had more cover by stumps and slash (Scott and Yahner 1989). Hares used brush piles in New York where conifers were absent or sparse (Richmond and Chien 1976). Old burns with cover in the form of brush and fallen woody debris can also be used extensively (Grange 1932). In Montana, dense clumps of Douglas fir within relatively open ponderosa pine forests were used by hares (Adams 1959). In summary, the less barren a regenerating stand is, the more hospitable it may be to lynx and hare. Also, the larger the unit, the more important such structures may become. The number of unburned islands within a burned area increases with fire size, and the disturbed area has more irregular shape and edge with increasing fire size in Alberta (Eberhart and Woodard 1987).

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[21]Coyotes hunted in dense habitat along with lynx in mature forest lynx habitat in Kluane, Yukon (Murray et al. 1994). However, dense patches of spruce only made up 2% of the land area and were likely small patches within the forest. The same effect might not be seen if the patches of spruce were larger. This situation illustrates the need for further research on the role of patch size and edge pertaining to managing prey habitat to benefit lynx.

Remnant material may also provide a lingering benefit of within-stand diversity that is characteristic of prime hare habitat. Interspersion of vegetation/slash is likely better for hares than uniform forests (Morse 1939, Conroy et al. 1979, Ferron and Oulette 1992). Also, lynx visually search for prey from piles of slash and snow (i.e. forming over remnant vegetation and debris) on the Kenai Peninsula, Alaska (Staples 1995).

d. Regeneration techniques will reflect the unit's potential to produce quality hare habitat (unit quality, according to vegetation association) and may involve use of fire or soil scarification techniques.

Not all forested sites may be able to attain stem densities preferred by hares. For example, Envirodata Systems, Inc. (1993) rated lodgepole pine stands on ABLA2/VACCI, ABLA2/LIBOL, and ABLA2/CARU associations as having higher potential to produce lynx habitat than ABLA2/VASC/CARU, ABLA2/VASC, and ABLA2/RHAL associations (Fig. 9 and Table 12). Also, clearcutting alone or clearcutting followed by slash burning may not mimic fire in regenerating lodgepole pine stands. By leaving the soil less physically disturbed, opening serotinous cones, and providing many snags that shade new seedlings from the sun and protect them from the frost, regeneration after fires may be excessive whereas after harvest, regeneration may be poor or absent (Okanogan Area, ABLA2/VASC associations, Williams and Lillybridge 1983).

7. Small Ecosystem/Ecological Communities. Quality snowshoe hare browse and cover within Forage Habitat will be maintained by providing horizontal cover densities >40% for 3.3 feet (1m) above average snow level using a vegetation profile board, viewed from 15m in four directions, according to the procedure outlined by Nudds (1977, distance of 15m to be verified during monitoring).

Adams (1959) qualitatively asserted the positive relationship between cover density and hare density in Montana. Brocke (1975) measured cover density and related it to hare density and concealment from predator in New York. Cover densities >40% within 3-5 feet (1-1.5 m) explained 85% of winter hare habitat use in northern Utah (Wolfe et al. 1982) and >60% within 7 feet (1-2 m) of the ground were used intensively in Maine (Litvaitis et al. 1985b). "Refuges" with cover densities of ~75% (up to 12 feet or 4 m tall) were used by hares in winter near Fairbanks, Alaska (Wolff 1980). Cover 3-10 feet (1-3m) above ground in the form of 50-60% conifer foliage cover values was identified as the single most important factor influencing snowshoe hare distribution in New Brunswick (Parker 1986).

Too much of a good thing is possible, of course, such as stands that are so dense that no browse grows within a hare's reach. All of the above authors observed seasonal shifts in habitat use by hares to relatively more open (but still with cover) areas outside of winter. Orr and Dodds (1982) found lower hare densities in forests with trees >40 feet (12m) tall and canopy closures of 60% (Nova Scotia). Adams (1959) observed that stands that were too dense to allow growth of forbs on the grounds were less used than less dense stands but both categories were used more than open stands (Montana).

Although stem density and horizontal cover are correlated, the relationship is not precise (Swayze 1995) and is not as clear as horizontal cover density (Litvaitis et al. 1985b). Nonetheless, stem densities reported in the literature are consistent across the hare's range: stands with approximately 6,000-14,000 stems/acre intensively used by hares, especially in winter (Brocke 1975; Wolff 1980; Sullivan and Sullivan 1982, 1983; Litvaitis et al. 1985a,b; Monthey 1986; Koehler 1990b; Swayze 1995). In the Methow Basin, stems within hare's winter reach (max. lowest live limb = 3.3 feet or 1m) were still available at these high stem densities (Swayze 1995).

The critical characteristic of vegetation height within Forage Habitat is derived from the hare's limited ability to reach for browse above ground or snow level. Browse heights reported for snowshoe hare are generally within two to three feet (60-85 cm) of average snow level (de Vos 1964, Bider 1965, Brocke 1965, Grigal and Moody 1980, Stephenson 1985, Parker 1986, Pease et al 1979). Higher browse may be available to hares as the weight of winter snow depresses branches (de Vos 1964).

a. Browse and cover tree species will be provided by species preferred by hares (according to the vegetative association), if preferred species are identified for the area. Otherwise, regeneration efforts will focus on creating the structure (cover density) preferred by hares, rather than the species (Ferron and Oulette 1992).

In northcentral Washington, Koehler (1990b) observed highest densities of hares in 20 yr. old lodgepole pine stands, but all other sampled forest types were ≥43 yr. old and therefore not likely to have the structure preferred by hares. However, high hare densities reported in dense lodgepole pine stands in the following locations also implicate the importance of lodgepole pine as snowshoe hare habitat: British Columbia (Sullivan and Sullivan 1982, 1983), Montana (Koehler et al. 1979), and Yukon (Slough and Ward 1990). Also, deVos (1964) suggested that pines are preferred browse.

Other coniferous species may provide snowshoe hare habitat, especially in the eastern-most zones of lynx habitat in Washington (i.e. western hemlock and western red cedar, pers. obs.). This probability is supported by the broad array of conifer species used by hares in other regions: Douglas fir (Bull Island, Flathead Lake, Montana, Adams 1959); red spruce (West Virginia, Brooks 1955; New Brunswick, Parker 1984); jack pine and black spruce (Hubbard County, northcentral Minnesota, Pietz and Tester 1983); balsam fir, eastern arborvitae cedar, and white spruce (Itasca County, northcentral Minnesota, Fuller and Heisey 1985); subalpine fir (48% of total collected pellets) and Douglas fir (28%) (northern Utah, Wolfe et al. 1982); subalpine fir (26 pellets/plot) and lodgepole pine (19 pellets/plot) (Utah, Clark (1973) in Dolbeer and Clark 1975); and mixed Engelmann spruce and subalpine fir forests and mixed spruce-fir-lodgepole pine forests (Colorado, Dolbeer and Clark 1975).

b. Thinning, partial harvests, lopping, or other treatments that may prolong forage conditions and/or to create forage opportunities in understories of mature stands will be considered.

Although thinning Forage Habitat may temporarily reduce the quality of a stand as lynx habitat (Sullivan and Sullivan 1988), it may have long-term benefits by prolonging forage conditions within the stand. For example, thinning can release understory shrubs preferred by hares (willow, *Salix* spp.) and make trees within the unit more accessible to hares by decreasing the distance of the lowest branch to the ground (C. Lee, Wenatchee Natl. For., pers. commun. and unpubl. field trip notes, Interagency Lynx Committee). Brooks (1955) found "fair" hare populations in second growth hardwood forests with a shrubby, ericaceous understory. On lodgepole sites, Envirodata Systems, Inc. (1993) suggested thinning at 12 years on "good" sites and 22 years on "poor" sites to maximize benefits to hares and lynx, but as discussed in the previous section, this is a topic that needs to be explored with controlled experimentation.

8. *Small Ecosystem/Ecological Communities*. Denning Habitat identified for the purpose of meeting the 10% per LAU minimum requirement stated in [4], where DNR manages 20% or more of a LAU, will be selected according to the criteria below.

a. First priority Denning Habitat will contain known lynx den sites. WDFW will provide the locations of known lynx dens to ensure that stands which currently or historically supported lynx dens are protected.

b. Second priority Denning Habitat will be identified in pre-sale harvest unit inventories. Denning Habitat will contain suitable denning structure such as deadfall arranged to provide structural diversity 1-4 feet (0.3-1.2 m) above ground. Stands that are 5 acres (1ha) or greater with more than one potential den site will receive highest priority. Preference will be given to stands as indicated below. Den sites are discussed under [10].

Koehler (1990a) described four dens (two by each of two females) in northcentral Washington as containing an average of 40 logs per 150 feet (50 m) of sample transect. Koehler and Aubry (1994) later described the debris as >1 log/3.3 feet (1 log/m), 1-4 feet (0.3-1.2 m) above ground. Windfall, insect or disease die-offs, and fire have historically been the source of this debris. This structure may be the most important characteristic of Denning Habitat, as suggested by Koehler and Brittell (1990) and discussed under 2.1.3 above (Table 5). However, the den sites in Washington were in ≥250 year old Engelmann spruce/subalpine fire/lodgepole pine stands on N or NE aspects (Koehler 1990a).

I. mature to over-mature stands of spruce/fir or similar mesic association with north or northeast aspects

ii. stands that have mesic associations with other aspects

iii. stands that have mature to over-mature overstories without mesic associations

9. *Small Ecosystem/Ecological Communities.* Potential human related disturbance to den sites will be minimized by locating potential den sites as far from roads as practical (goal 0.25 mile or 0.4 km, WDFW 1996), where DNR-manages 20% or more of a LAU.

WDFW (1996) recommended that harvest activity and use of motorized equipment be excluded within 0.25 mile of any known denning sites during the lynx breeding season (May 1- July 31). Koehler (1990a) did not detect a detrimental influence of his presence at den sites on kitten survival. However, in more accessible areas, local predators may have learned to associate human scents with food. It is most important to be sensitive to this acclimation when prey is scarce. Therefore, the denning site disturbance buffer should also apply to passive human disturbance until lynx densities recover from threatened status.

10. *Small Ecosystem/Ecological Communities.* To ensure that den sites are available across the landscape, at least two den sites per square mile will be provided. Many den sites will overlap with the Denning Habitat identified in LAU's where DNR manages at least 20% of the area, as indicated in [4], above. Den sites will contain suitable denning structure, such as deadfall layered to provide structural diversity 1-4 feet (0.3-1.2 m) above ground. Larger deadfall diameters will be selected over smaller diameters (WDFW 1996). Priority for den site selection will be as follows:

WDFW (1996) recommended logs ≥6" (15 cm) in diameter. Larger diameter logs likely have higher value as denning structure because they decay slower and provide a greater amount of and sturdier cover.

a. Known den sites.

b. Den sites within Denning Habitat, following priorities listed under [8.b].

c. Den sites within other types of lynx habitat:

I. sites within Travel Habitat

ii. sites within Forage Habitat

iii. sites within Temporary Non-lynx Area

d. If no existing denning structure can be found, den sites may be artificially constructed. DNR's region biologist will coordinate with WDFW to survey existing den sites and recommend details of artificial den size and structure. In addition:

I. Logs used for artificial den site creation will reflect what is available on the site and within each square mile section.

If logs >6" (15cm) are available within a LAU, den site creation will be planned there. However, not all Denning Habitat that lynx occupy support such diameters. If no large diameter logs are available, log sizes used will reflect the largest available and their effectiveness should be monitored.

ii. The maximum number of jack-strawed down logs possible will be used to create artificial den sites, given regeneration concerns and log availability.

iii. Sites on north or northeast aspects will be selected over other aspects, if available.

iv. Sites with mesic plant associations will be selected, if present.